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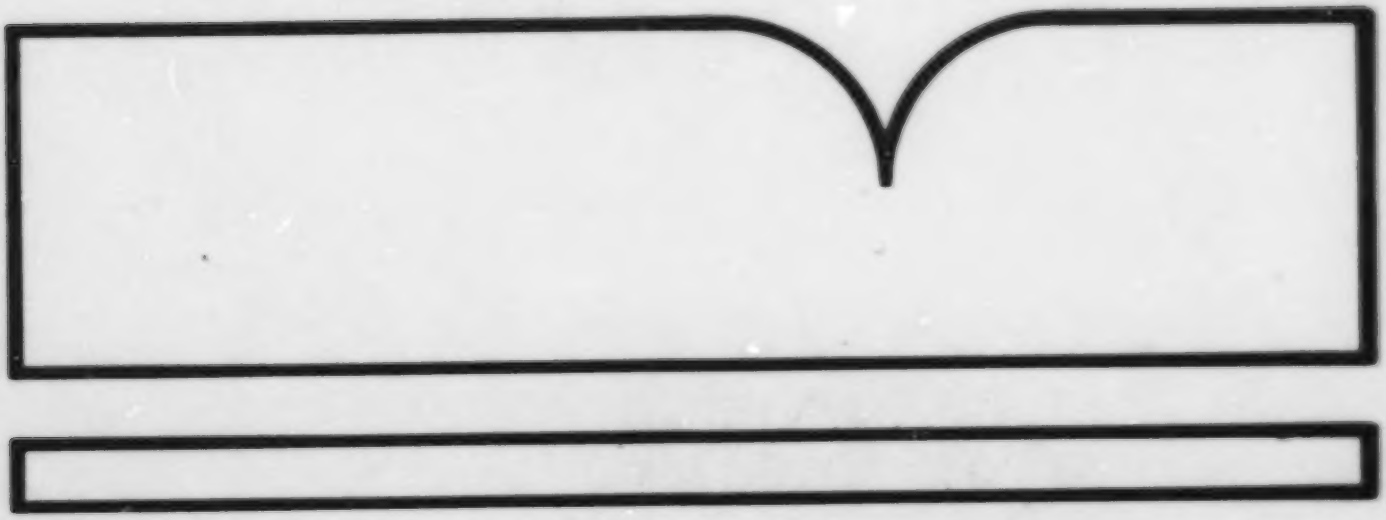
Residential and Commercial Area Source Emission Inventory Methodology for the Regional Air Pollution Study

Environmental Science and Engineering, Inc.
Gainesville, FL

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Sep 75



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September 1975

RESIDENTIAL AND COMMERCIAL AREA SOURCE EMISSION INVENTORY METHODOLOGY FOR THE REGIONAL AIR POLLUTION STUDY

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One of the major objectives of the Regional Air Pollution Study (RAPS) is to provide data on the emissions of air pollutants, meteorological conditions and ambient air quality with unprecedented density and resolution as to allow the testing and development of a spectrum of mathematical models to simulate relationships between emissions of pollutants and air quality. As part of this effort a methodology for estimating the pollutant emissions from stationary residential and commercial-institutional area sources on an hour-by-hour basis, and apportioning them to the RAPS grid system is presented.

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RESIDENTIAL AND COMMERCIAL AREA SOURCE EMISSION INVENTORY METHODOLOGY FOR THE REGIONAL AIR POLLUTION STUDY

by

Environmental Science and Engineering, Inc.
Gainesville, Florida

Contract No. 68-02-1003

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
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September 1975

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INTRODUCTION

One of the major objectives of the Regional Air Pollution Study (RAPS) is to provide data on the emissions of air pollutants, meteorological conditions and ambient air quality with unprecedented density and resolution as to allow the testing and development of a spectrum of mathematical models to simulate relationships between emissions of pollutants and air quality. Crucial to the achievement of this objective is an emissions inventory cataloging the pollutant emissions of the St. Louis region on an hour-by-hour basis. As part of this effort, Environmental Science and Engineering, Inc. (ESE) has developed a methodology for estimating the pollutant emissions from stationary residential and commercial-institutional area sources on an hour-by-hour basis, and apportioning them to a grid system especially designed for the RAPS.

The boundaries of the region of interest are established as the St. Louis Interstate Air Quality Control Region (AQCR 70). ESE has collected data on fuel usage, distribution of residential and commercial-institutional land use, gasoline sales, paint sales, use of dry cleaning fluids, solid waste disposal and uncontrolled fires for the region, analyzed such data and developed a series of models to estimate the area emissions of sulfur dioxide, particulates, nitrogen oxides, hydrocarbons and carbon monoxide for each specified grid square shown in Figure 1.1. A temporal allocation procedure was then developed from the data to define emissions on an hourly basis.

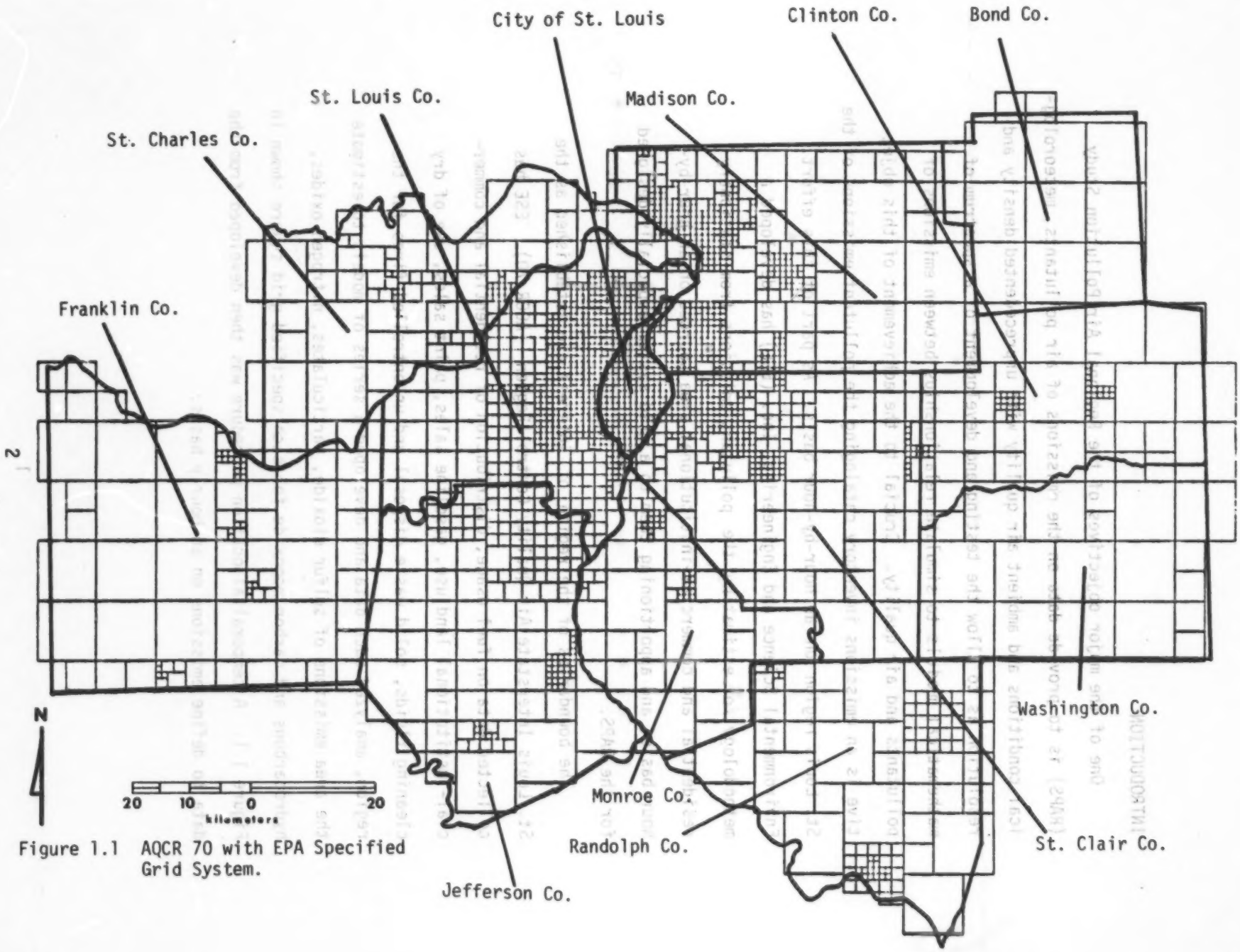

Figure 1.1 AQCR 70 with EPA Specified Grid System.

RESIDENTIAL AND COMMERCIAL-INSTITUTIONAL FUEL USE

Residential and commercial-institutional burning of fuels for space heating and other functions in urbanized areas has long been recognized as an important source of pollutants. The spatial distribution of the emissions from such fuel burning to the specified Environmental Protection Agency (EPA) grid system (Figure 1.1) was accomplished by analysis of population and commercial land use density from census tapes; The East-West Gateway Coordinating Council Report 1971-72 Existing Land Use Update and Analysis, St. Louis City Planning Commission St. Louis Development Program, and the Bureau of Census Population Estimates and Projections for 1972-73. Temporal distributions were obtained by an analysis of natural gas flow and billing data obtained from the LaClede Gas Company, with respect to time of day, ambient temperature and wind speed.

Fuel Use Emission Estimates

The emission estimates are based upon the National Emissions Data System (NEDS) Stationary Source Fuel Summaries Report. These values are shown in Table 2.1. The Fuel Summaries Report does not include information on bottled (LP) gas consumption for area sources. It has been assumed that the ratio of homes using bottled gas to natural gas is the same as the ratio of the BTU's consumed by users of bottled gas to the users of natural gas. As bottled gas is relatively clean and is not of major concern in the urbanized areas, this assumption appears reasonable. Revisions of annual fuel summary figures are readily translated into revised emissions, per grid, through direct proportionality factors.

Estimated sulfur and ash contents of the bituminous coal used for

Table 2.1 Fuel Summaries Report, National Emissions Data System, Annual Area Source Fuel Usages.*

LOCATION	FUEL TYPE					
	BITM. COAL (Tons)	RESID. OIL (10^3 Gal.)	DIST. OIL (10^3 Gal.)	NAT. GAS (10^6 Cu.Ft.)	WOOD (Tons)	BOTTLED** (LP) GAS (10^3 Gal.)
Bond Co., Ill.						
Residential	5520	--	2350	290	200	5474
Industrial	710	30	40	60	--	--
Commercial-Institutional	--	760	--	170	--	--
Clinton Co., Ill.						
Residential	8200	--	2880	640	200	8806
Industrial	2490	110	130	210	--	--
Commercial-Institutional	--	1530	--	350	--	--
Madison Co., Ill.						
Residential	63150	--	21730	8040	400	39632
Industrial	64540	2840	3490	5570	--	--
Commercial-Institutional	--	13600	--	3120	--	--
Monroe Co., Ill.						
Residential	4180	--	1910	220	200	13339
Industrial	180	10	10	20	--	--
Commercial-Institutional	--	1020	--	240	--	--

*

** See Footnotes on following page.

Table 2.1 Fuel Summaries Report, National Emissions Data System, Annual Area Source Fuel Usages.* (Continued)

LOCATION	FUEL TYPE					
	BITM. COAL (Tons)	RESID. OIL (10^3 Gal.)	DIST. OIL (10^3 Gal.)	NAT. GAS (10^6 Cu.Ft.)	WOOD (Tons)	BOTTLED** (LP) GAS (10^3 Gal.)
Randolph Co., Ill.						
Residential	13070	--	3190	440	--	13506
Industrial	4620	200	250	400	--	--
Commercial-Institutional	--	1700	--	390	--	--
St. Clair Co., Ill.						
Residential	86210	--	23410	8370	1000	44919
Industrial	30760	1350	1660	2660	--	--
Commercial-Institutional	--	15450	--	3540	--	--
Washington Co., Ill.						
Residential	6220	--	1810	330	800	9784
Industrial	1070	50	60	90	--	--
Commercial-Institutional	--	740	--	170	--	--
Franklin Co., Mo.						
Residential	2260	--	5600	1090	4600	55558
Industrial	31710	920	350	780	--	--
Commercial-Institutional	--	850	1220	1600	--	--

*

** See Footnotes on following page.

Table 2.1 Fuel Summaries Report, National Emissions Data System, Annual Area Source Fuel Usages.* (Continued)

LOCATION	FUEL TYPE					
	BITM. COAL (Tons)	RESID. OIL (10^3 Gal.)	DIST. OIL (10^3 Gal.)	NAT. GAS (10^6 Cu.Ft.)	WOOD (Tons)	BOTTLED** (LP) GAS (10^3 Gal.)
Jefferson Co., Mo.						
Residential	1080	--	5350	2860	2200	89537
Industrial	--	90	60	2970	--	--
Commercial-Institutional	--	--	80	10580	--	--
St. Charles Co., Mo.						
Residential	1520	--	4940	2480	700	56341
Industrial	--	20	560	180	--	--
Commercial-Institutional	--	--	620	190	--	--
St. Louis Co., Mo.						
Residential	4760	--	22020	34450	500	44512
Industrial	33500	3760	--	17720	--	--
Commercial-Institutional	--	--	--	--	--	--
St. Louis City, Mo.						
Residential	18560	--	13560	26400	1800	16619
Industrial	100,000	800	10000	28600	--	--
Commercial-Institutional	112,000	--	35000	11100	--	--

* Industrial area sources were not considered in this study; the fuels summary includes these values for comparison purposes.

**Calculated fuel usage.

calculating emissions were 2.5 percent and 5 percent,* respectively. These figures must be taken as representative, but they are subject to large variations. The percentage of homes using coal for heating may, at first glance, appear to be insignificant; however, 0.3 percent of the homes in St. Louis County burning an average Illinois coal containing 2.5 percent sulfur generates almost half as much sulfur dioxide emissions as the 9 percent of the homes burning distillate oil containing typically 0.2 percent sulfur.** Careful monitoring of the sulfur and ash content of coal sold for residential use will be required to attach greater confidence to the sulfur dioxide emissions estimates from coal combustion by residential users at any point in the future.

Emissions from wood combustion were found to be insignificant and are therefore not included in the computer routine for emissions computations.

All emissions estimates are based upon the emission factors utilized by the National Emissions Data System.

Spatial Resolution

Residential Fuel Usage - The U. S. Bureau of Census Fourth Count Computer Summary Tapes contain data on size and nativity of families, education, employment status, age of home, and fuel usage for space-heating, water-heating, and cooking for census tracts, county subdivisions, and counties. The determination of the spatial distribution of residential fuel usage was estimated from the data on these tapes for the tracts in the St.

---

* Average of proximate analyses for coals from Saline, Perry, and Sangamon Counties, Illinois.

** Average of typical analysis for No. 1 and No. 2 fuel oil.

Figure 2.1

CENSUS TRACTS IN THE ST. LOUIS, MO.-ILL. SMSA AND ADJACENT AREA

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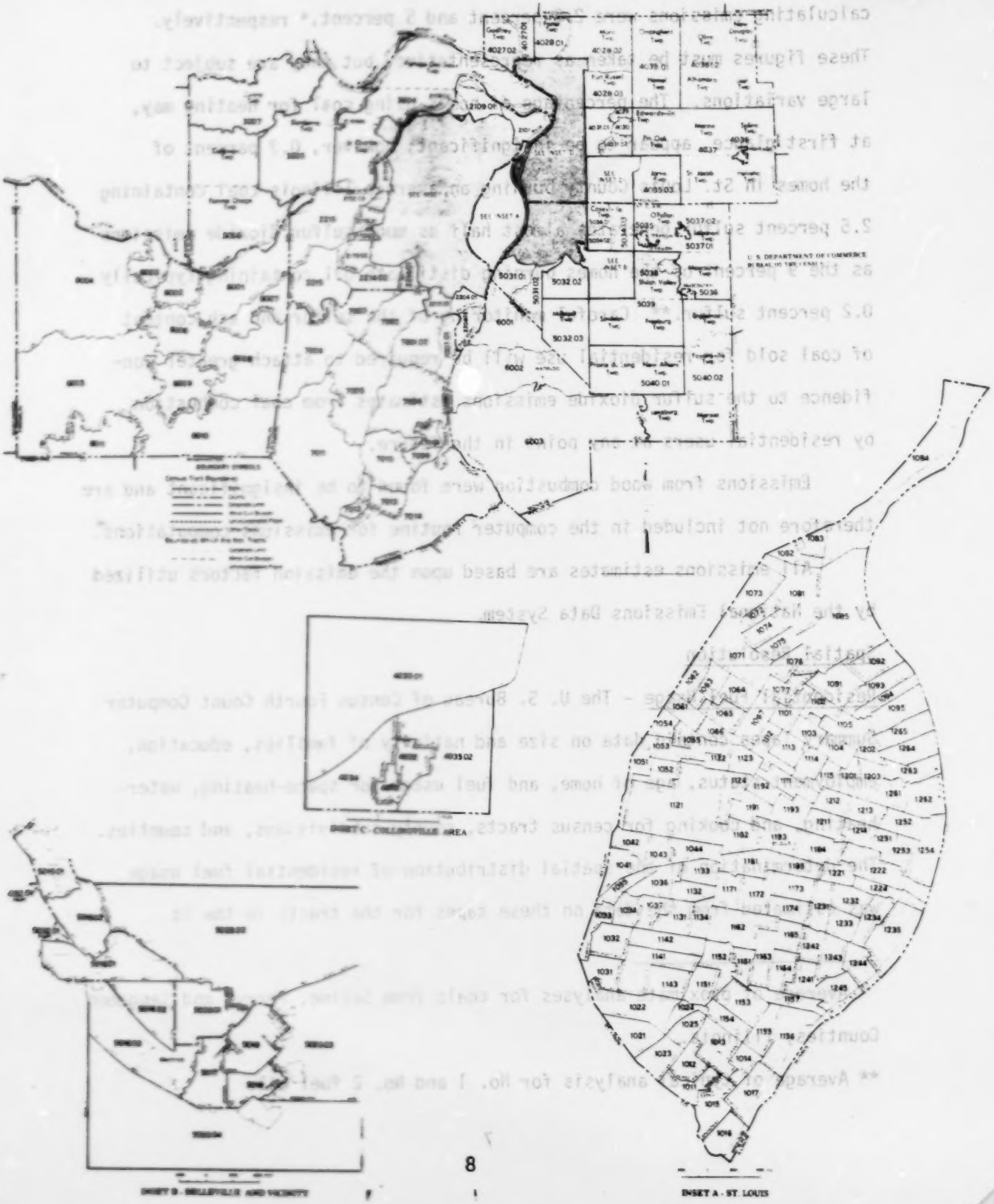
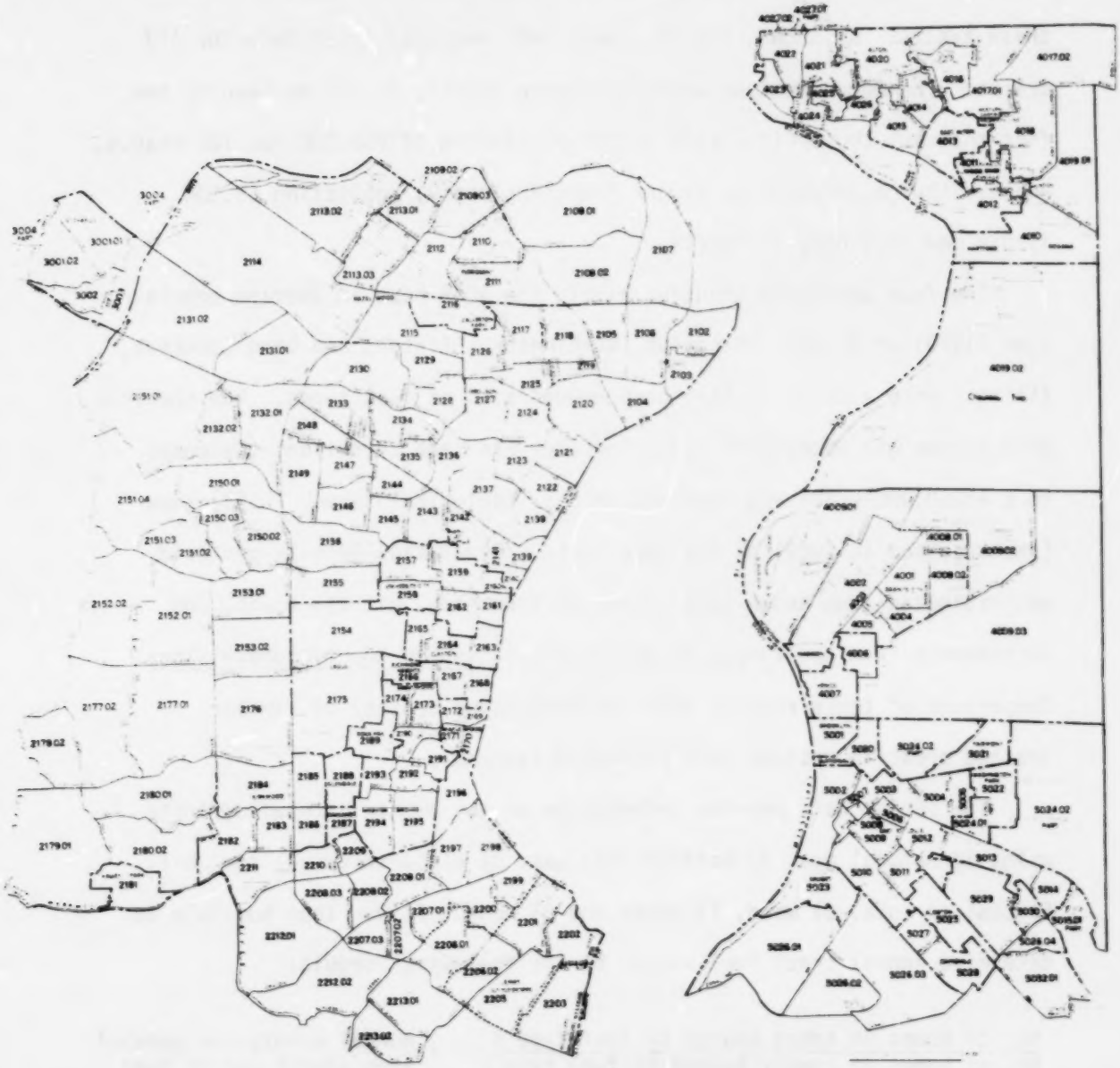


Figure 2.1, cont.



INSET E - EASTERN ST LOUIS COUNTY

INSET D - WESTERN PART OF MADISON AND ST CLAIR COUNTIES

Louis Standard Metropolitan Statistical Area (SMSA). Figure 2.1 shows these tracts. As shown, the St. Louis SMSA included tract data for 417 tracts. The more populous areas have more tracts, as can be seen by the fact that St. Louis City, with a 1970 population of 950,000 has 126 tracts, whereas the geographically larger Franklin County, population 55,000 is divided into only 11 tracts.

The four untracted counties within the AQCR have an average population (1970) of 22,000. Randolph, Washington, Clinton, and Bond Counties, Illinois were assumed to have homogeneous uses of fuel types. The specific grid system was reproduced using Computer Plotting Techniques (Calcomp) to a 1:250,000 scale and overlain on U.S. Geological Survey (USGS) maps (photorevised in 1969) of the same scale. Population Density per grid was estimated from known populations of townships, cities, towns, and settlements from the Bureau of Census Population of County Subdivisions. Comparison of these results with the population density of similar tracted areas in western AQCR 70 proved favorable.

The census data provide information on the number of housing units using 1) natural gas, 2) bottled (LP) gas, 3) electricity, 4) fuel oil, 5) coal or coke, 6) wood, 7) other and 8) none. It was thus possible to determine annual tract fuel usages by the following formula:

$$\frac{\text{No. of homes in tract heated by fuel type i}}{\text{No. of homes in county heated by fuel type i}} \times \text{annual county residential area source use of fuel type i}$$

The annual county residential area source fuel usage of each fuel type was available from the EPA NEDS Stationary Source Fuel Summary Reports for the respective counties.

The major difficulty with using census tract data consists of accurately determining the tract(s) in each square of the specified EPA grids. Using detailed USGS 7.5 minute series maps, the relationship between the census tract maps and the EPA grid system was graphically determined. Calcomp was again utilized to obtain the EPA grid system on the same scales as the available tract maps. Every grid square was listed with a visually estimated land area percentage of the total tract area of each tract contributing to the land area of the grid. The estimated tract areas which resulted were then normalized to insure that exactly 100 percent of each tract had been apportioned among the grid system.

This procedure allowed elimination of special terrain and land use effects. Significant deviations from land use typical of the overall census tract occur primarily along the banks of the Mississippi River; near Forest Park in St. Louis city; near Lambert Field; near Washington University; and near Grant's Farm. Although these areas were included in the tract information, zero percent of the pertinent tract was apportioned to the affected grid squares. Near the Mississippi River, portions of the tracts over the water were similarly excluded in determining the percentage of the tract lying within a given grid.

For Bond, Clinton, Randolph, and Washington Counties, Illinois (the untracted counties) all grids falling within those counties were artifically designated as tracts for computational purposes, and tract numbers were assigned corresponding to their EPA grid numbers (thus EPA Grid 1632 falling in Randolph County was said to contain 100 percent of "Tract 1632").

Tract data was then created for each grid-tract using the Population Density Per Grid, Number of persons per housing unit, and Percentage of housing units using the various fuels. These data are available for each county in the Bureau of Census Detailed Housing Characteristics. Thus for competitional purposes, tract data were created in the same format as the available tract data for the counties within the SMSA.

Utilizing these techniques, a high degree of reliability can be attached to the spatial resolution of area source emissions due to residential fuel consumption.

Commercial-Institutional Fuel Usage - Apportioning commerical-institutional fuel usage involved the same basic problems as that of residential fuel use. These problems are those of determining where the commercial use occurs and of determining the type of fuel used.

The Bureau of the Census gathered data of a different kind for business than those gathered for housing.* Furthermore, problems of confidentiality for geographic areas smaller than an SMSA occur.**

Therefore, in order to determine the distribution of commercial land usage, the 1971-1972 Existing Land Use Update and Analysis, prepared by the East-West Gateway Coordinating Council (EWGCC) was utilized. The

---

* This data included number of reporting units, payroll, and employment by industry and county location.

** In accordance with Federal Law, data that disclose the operations of an individual employer are not published. Data are not shown separately for any industry that does not have at least 100 employees or 10 reporting units in the statistical area.

St. Louis SMSA was divided into 5,000 feet by 5,000 feet grids, with nine scalings for the percent of land use within each grid. The land use was indicated as zero, less than one, 1-10, 10-20, 20-30, 30-40, 40-60, 60-80, and 80-100 percent of land use within the grid as being utilized for a given purpose. The EPA specified grid system was plotted with computer techniques (using the Calcomp plot routine) to the same scale as the EWGCC grid maps of the St. Louis SMSA. The EPA grid was then overlayed on the EWGCC map. The number of each category of EWGCC grid squares lying within an EPA grid was recorded. Based on the total number of EWGCC grids lying within an EPA grid, it was possible to determine the commercial land use area within each of the EPA grid squares. The commercial land use area within each grid (CLUG) square is thus:

$$\text{CLUG} = \left(\frac{\sum_{i=1}^{9} \text{no. of EWGCC grids of commercial \% } i \times \frac{\text{percentage category } i}{100}}{\text{total no. of EWGCC grids within the EPA grid}} \right) \times \text{total land area of the EPA grid } (\text{km}^2)$$

where the percentage categories were treated as zero, 0.5, 5, 15, 25, 35, 50, 70, and 90 (the midpoint of each range).

Using the same approach, the total commercial land use within each county (CLUC) was determined. This approach enabled ESE to determine the spatial distribution of commercial land usage.

The fuel consumed by commercial-institutional establishments was assumed to have the same relative distribution, as to the type of fuel, as utilized for space heating by residences in a given area.[1] The simplist approach would be to assume each grid's portion of its counties full use in proportion to its fraction of counties commercial-institutional

land use. This leads to inaccuracies because certain grids are "enriched" in some fuels because of the fuel distribution system, particularly gas mains. Thus a few of the grids may account for the vast majority of a county's use of a particular fuel. To account for this problem, an "enrichment factor" was applied to the result of the land use distribution calculation. This "enrichment factor" was equal to the ratio of the fraction of residences in a given grid using a given fuel to the fraction of residences using the same fuel in the county. The assumption is that the residential and the commercial-institutional "enrichment factor" are equal for any grid.

The annual commercial-institutional fuel use total per grid is thus:

$$\text{Annual Fuel Use} = \frac{\text{CLUG}}{\text{CLUC}} \times \begin{pmatrix} \text{County Total Area} \\ \text{Source Commercial} \\ \text{Use of Type of Fuel} \end{pmatrix} \times \text{EF}$$

where: EF = the "enrichment factor" and

$$\text{EF} = \frac{\left(\dfrac{\text{No. of homes in grid using j type of fuel for heat}}{\text{Total number of homes in grid}}\right)}{\left(\dfrac{\text{No. of homes in county using j type of fuel for heat}}{\text{Total number of homes in county}}\right)}$$

The data for the fraction of homes in the various counties using each type of fuel are summarized in Table 2.2.

Temporal Distribution of Fuel Usage

After a great deal of effort to reduce electrical demand data specific for residential, commercial, and industrial areas to produce different energy demand functions of time, an assumption was made that residen-

Table 2.2 Fuel Use for Occupied Housing Units, by County, Within AQCRE 70. *

County	% Urban	Utility Gas %	Fuel Oil %	Coal %	Wood %	Electricity %	LPG %	Other & None %
Missouri								
Franklin	46	6	41	2	3	7	40	1
Jefferson	19	32	22	1	1	7	37	0
St. Charles	50	42	24	1	0	7	27	0
St. Louis	96	85	10	0	0	3	2	0
St. Louis City	100	86	8	2	0	2	1	1
Illinois								
Bond	34	40	36	5	0	4	14	1
Clinton	32	60	17	6	0	3	14	0
Madison	74	71	16	4	0	2	6	1
Monroe	50	46	20	3	0	2	28	1
Randolph	43	49	24	8	0	2	17	0
St. Clair	83	69	16	6	0	2	6	1
Washington	22	35	21	14	2	2	26	0

* Bureau of the Census Detailed Housing Characteristics for Illinois and Missouri, 1970.

tial and commercial-institutional fuel use temporal distribution was the same. The most extensive data base consisted of hourly natural gas flow data from the LaClede Gas Company. The analysis of this data produced a "BTU demand" model to estimate space heating and appliance demands for fuel consumption over time.

Data-Fuel Usage -

Electrical Demand - Since overall electrical system data was not available in a form that would allow analysis by grid area and service type, it was decided to obtain base data from three substations selected because they served predominantly residential, commercial and industrial areas respectively. The data obtained was in the form of circular charts which were digitized. Analysis of the data revealed gaps in the data and internal inconsistencies which could not be resolved with the available data. For these reasons, the data proved to be of little value to the project.

Natural Gas Flows - Hourly gas flows in MCF for the LaClede, St. Louis gas system were obtained in tabular form for January through November of 1974 and October, November and December of 1973. This was converted to machine readable form and used extensively in the analysis procedure described below to develop patterns of usage by various parametric classifications.

Further, the LaClede Gas Company cooperated in supplying a copy of their billing history for the period specified on some twenty magnetic tapes to provide both the monthly consumption and the customer classifications.

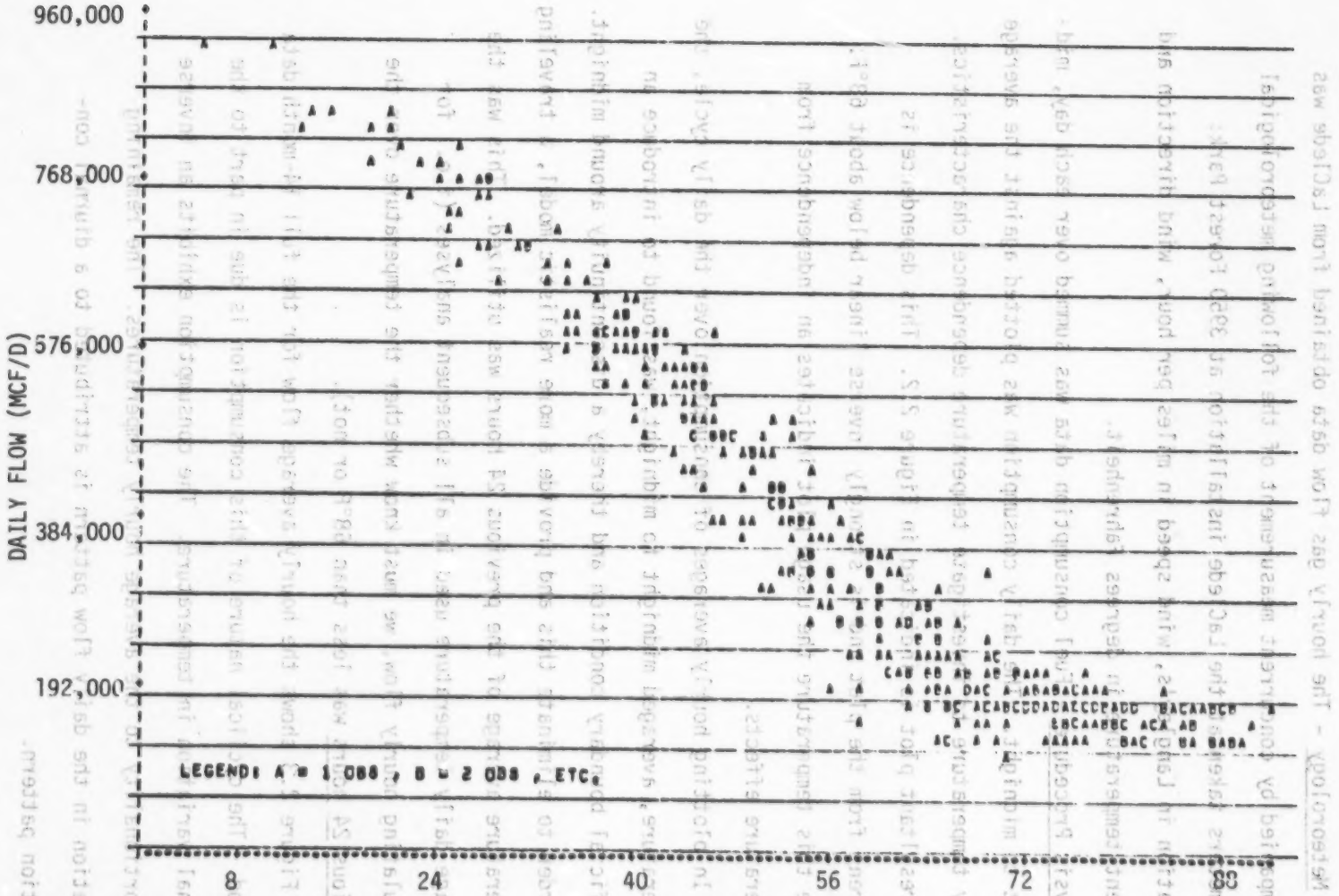
Meteorology - The hourly gas flow data obtained from LaClede was accompanied by concurrent measurement of the following meteorological parameters taken at the LaClede installation at 3950 Forest Park: radiation in Langley's, wind speed in miles per hour, wind direction and ambient temperature in degrees Fahrenheit.

Analysis Procedure - Fuel consumption data was summed over each day, midnight to midnight. The daily consumption was plotted against the average daily temperature to investigate temperature dependence characteristics. The resultant plot is indicated in Figure 2.2. This dependence is apparent from the plot and is strongly inverse linear below about 68°F. Above this temperature the usage plot indicates an independence from temperature effects.

In plotting hourly averages of consumption over the daily cycle, the temperature, averaged midnight to midnight, was found to introduce an artificial boundary condition and thereby a discontinuity around midnight. In order to eliminate this and provide a more realistic model, a traveling temperature average of the previous 24 hours was utilized. This was the average daily temperature used in all subsequent analyses (i.e., for calculating hourly flow, we must know whether the temperature over the previous 24 hours was less than 68°F or not).

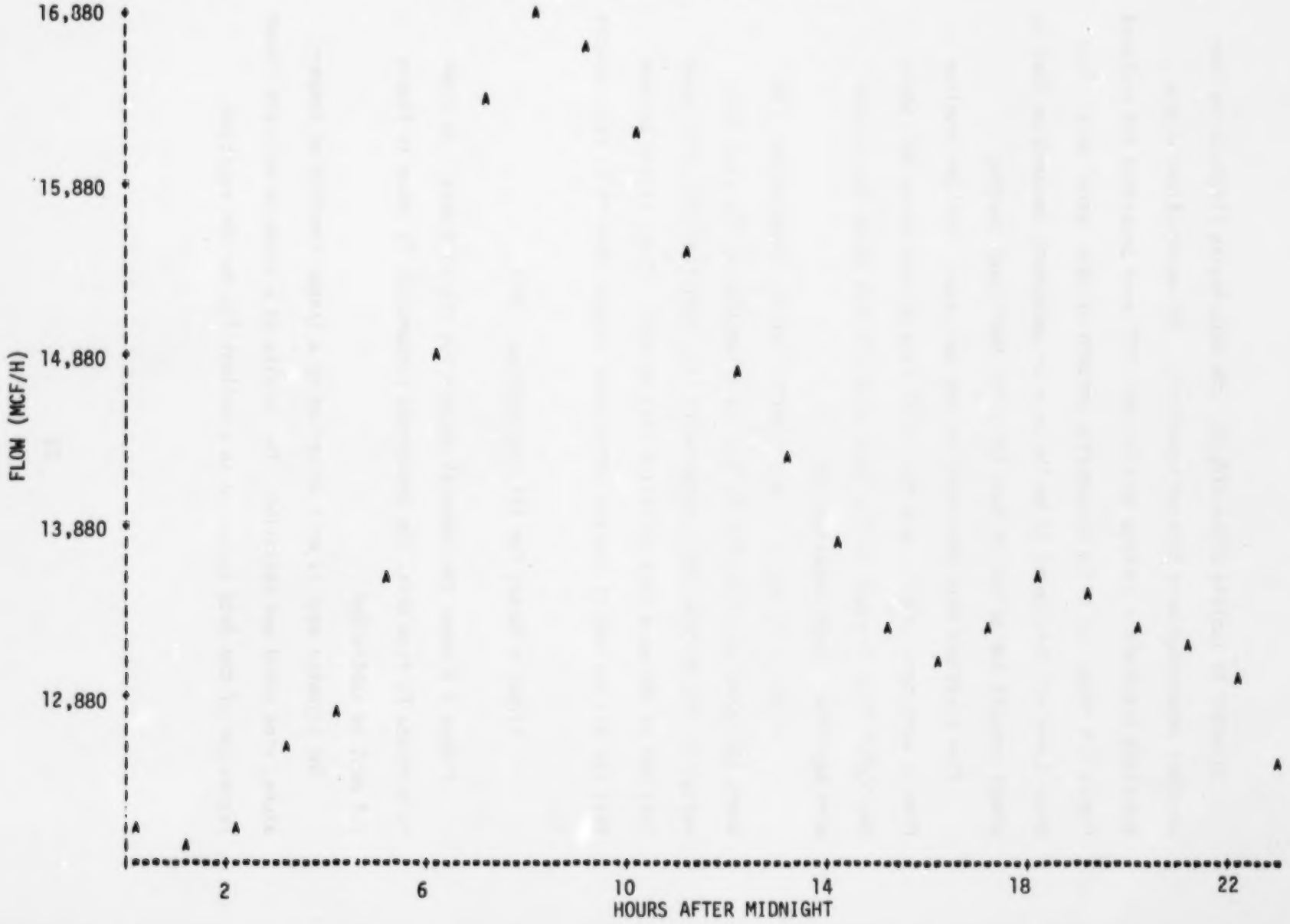
Figure 2.3 shows the hourly average flow for the full 14-month data period. The cyclical nature of this consumption is due in part to the diurnal variation in temperature. The consumption exhibits an inverse proportionality to the average hourly temperatures. The remaining variation in the daily flow pattern is attributed to a diurnal consumption pattern.

Figure 2.2 Daily Gas Flow Vs. Average Daily Temperature.



A = 1 Observation/pt.
B = 2 Observations/pt.
C = 3 Observations/pt.
Etc.

Figure 2.3 Average Hourly Total Flow.



In order to isolate these effects, the data having little or no temperature dependence were treated separately. The observations with a traveling temperature average greater than 68°F were separated and analyzed. Figure 2.4 shows the daily consumption pattern of this "warm" data. This usage curve was considered to be the base or background consumption that is always present due to use of fuel for other than space heating.

Flow equations were developed for the two cases: for the baseline flow on warm days (>68°F); and the "cold" flow on days below 68°F where the "cold" flow is equal to the total observed flow minus the average warm day flow. These equations are:

$$FT(hr) = FC(hr, T, R, WS) + FW(hr) \text{ For All Temperatures } \leq 68°F$$

where the total gas flow (FT) by hour is a function of the cold data variation (FC) by hour (hr), temperature (T), radiation (R), wind speed (WS) and of the warm data variation (FW) by hour. Thus, it can be seen that for all periods of average temperature greater than 68°F, this reduces to:

$$FT(hr) = FW(hr) \text{ For All Temperatures } > 68°F.$$

Figure 2.5 shows the temporal pattern for the cold data. In order to estimate FC from this, the background consumption FW shown in Figure 2.4 must be subtracted.

The adjusted data is well described by a linear function of temperature, wind speed and radiation. The results of a stepwise multiple linear regression of the data indicated an excellent fit for the equation:

Figure 2.4 Average Hourly Gas Flow for 24-Hour Average Temperature Greater Than 68°F.

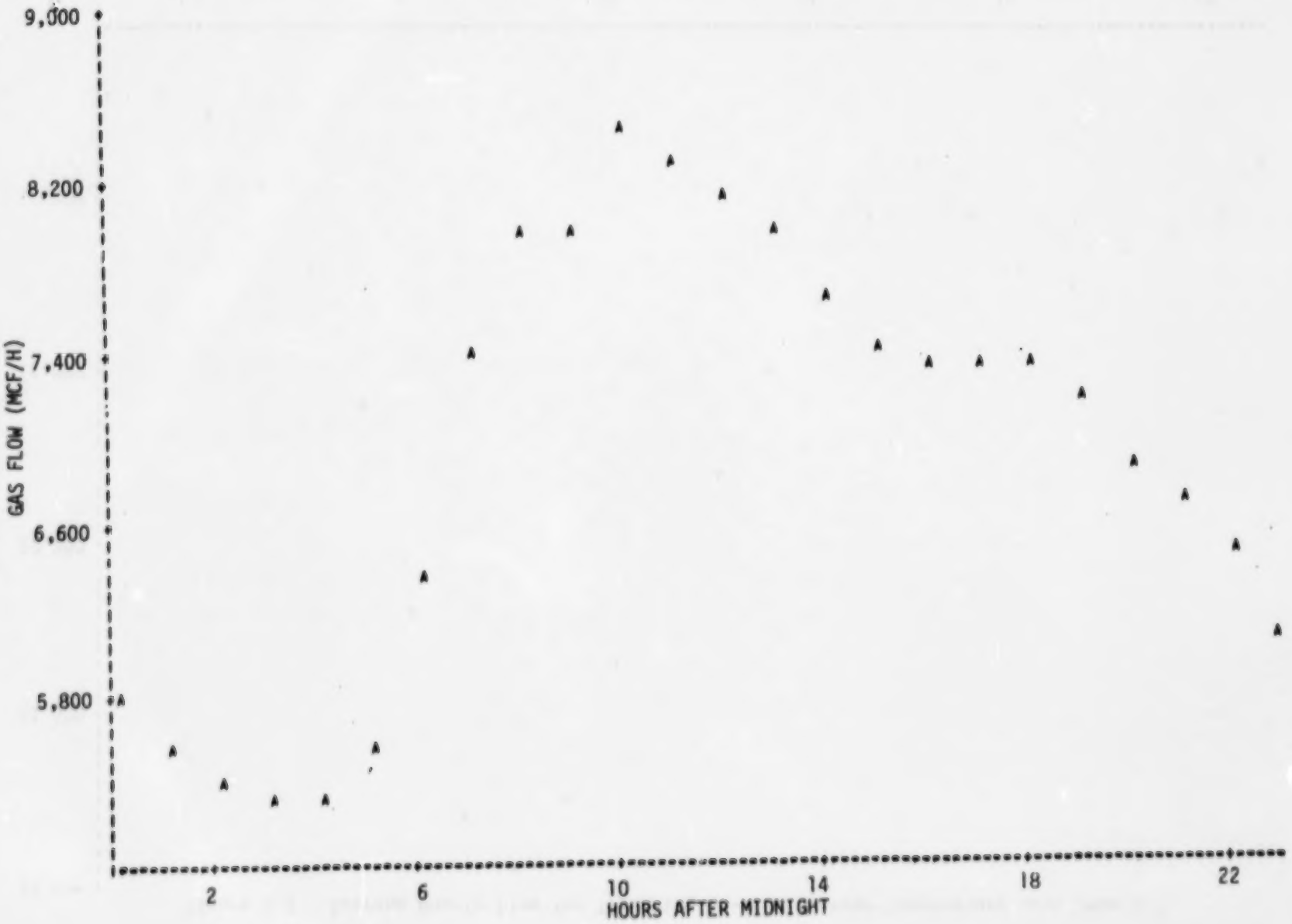
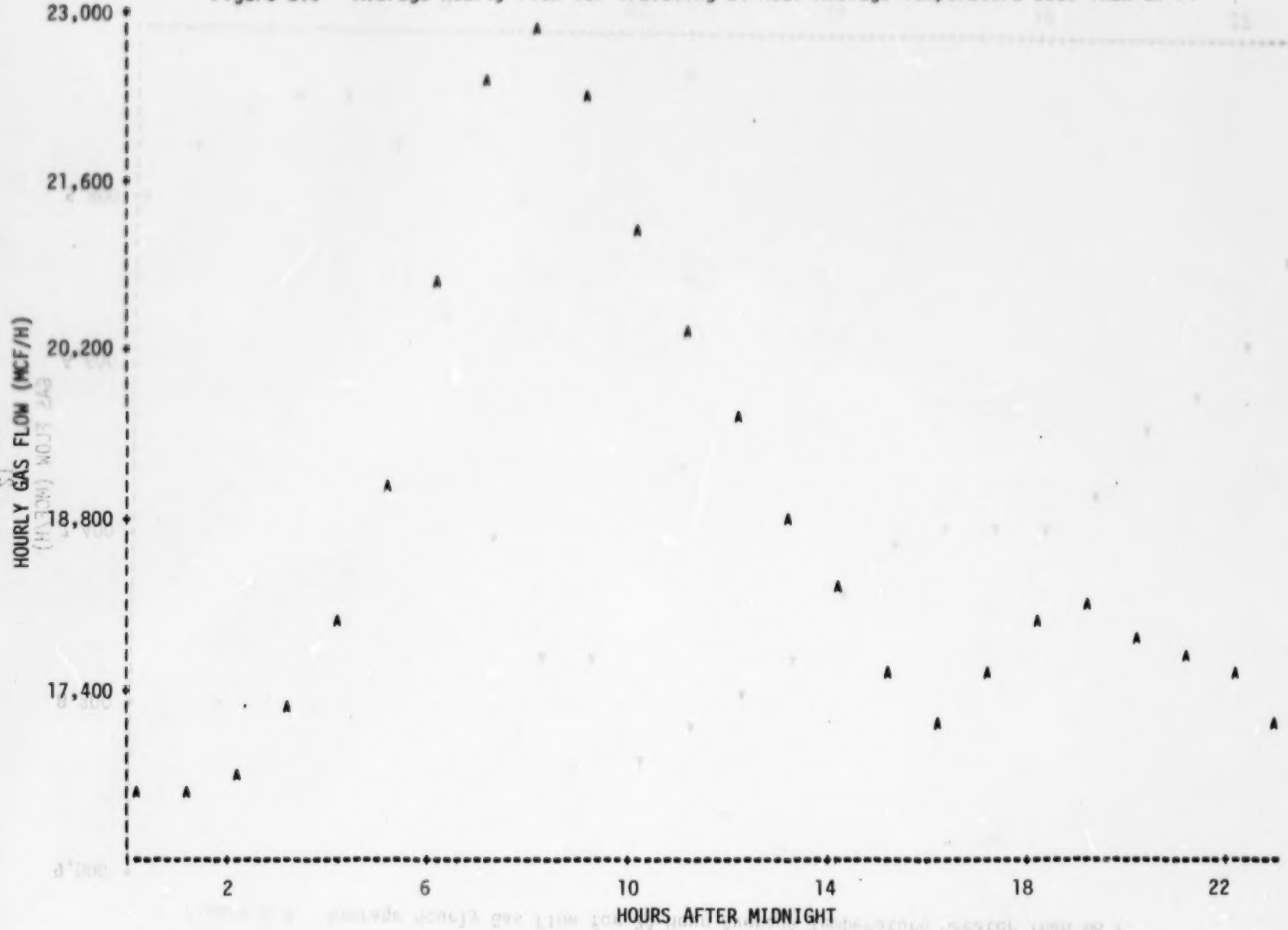


Figure 2.5 Average Hourly Flow for Traveling 24-Hour Average Temperature Less Than 68°F.



$$FC = 3.6798 \times 10^4 - 5.4507 \times 10^2 T + 1.0798 \times 10^2 R + 97.873 WS$$

where:

FC = total MSCF/hour attributed to heating use

T = temperature in °F

R = radiation in percent of two Langley's/min*

WS = wind speed in mph

The above regression equation would indicate that space heating demands increased with an increase in the intensity of solar radiation. This is contrary to the usual concept of the impact of solar radiation on space heating. Further investigation indicated that the highest recorded R values were in the autumn, and that the summer months contained a disproportionate number of low values, presumably due to clouds. In order to remove this potential problem in predicting fuel usage for a particular day or hour, the regression was repeated without a solar radiation term. The results are shown in Table 2.3 and the equation is:

$$FC = 3.4772 \times 10^4 - 5.0895 \times 10^2 T + 1.0478 \times 10^2 WS$$

where the variables are the same as defined previously. These results are similar to those obtained by the LaClede Gas Company in the development of a model for different purposes[2]. Integrated over the entire

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* The mean intensity of the solar radiation received at the boundary of the atmosphere ranges from 2.007 to 1.877 calories per cm^2 per minute (Langley's). Two Langley's/minute thus is the maximum radiation that could be received. The metered values used in this study thus represent a percent of this figure.

Table 2.3

REGR OF COLD DATA WITH WARM SUBTRACTED

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE FLW

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
2	0,87251673	TMP WS

THE ABOVE MODEL IS THE 'BEST' 2 VARIABLE MODEL FOUND BY THE MAXIMUM R-SQUARE IMPROVEMENT PROCEDURE

ANALYSIS OF VARIANCE TABLE , REGRESSION COEFFICIENTS , AND STATISTICS OF FIT FOR THE ABOVE MODEL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	2	383694469564,94880	191847234782,47440	21894,48820	0,0001	0,87251673	27,69507 %
ERROR	6398	56061534626,92543	8762353,02078				
CORRECTED TOTAL	6400	439756004191,87420					

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
TMP	1	381755450861,87660	43567,68667	0,0001	383568940190,12810	43776,93289	0,0001
WS	1	1939018703,07225	221,28973	0,0001	1939018703,07225	221,28973	0,0001

SOURCE	B VALUES	T FOR H0:B=0	PROB > ITI	STD ERR B	STD B VALUES
MEAN	34772,33225349				
TMP	-508,95257545	-209,22938	0,0001	2,43251009	-0,93534958
WS	104,77697749	14,87581	0,0001	7,04344682	0,06650157

fourteen months of available data from LaClede (i.e. 9780 hours of observations), the total predicted cold flow using this equation is 7.1697 x 10^7 MSCF. Over the same period the non-space heating or "baseline" flow accounted for 6.7027 x 10^7 MSCF (approximately 48 percent of the gas flow). The total 13.8724 x 10^7 MSCF is within 3% of the total LaClede data. (Total observed equals 13.5145 x 10^7 MSCF.)

The baseline flow is most appropriately represented as a composite average for the time periods when the traveling average 24-hour temperature exceeds 68°F. As seen in Table 2.4 the above fourteen month baseline flow reduced to an average hourly baseline flow is 6.854 MSCF. This table summarizes the hourly baseline flow by the hour and the proportionality factor (PF) by hour related to the average flow. Hourly baseline gas flow can then be approximated by:

$$\text{Hourly Baseline Flow (HBF)} = \frac{\text{yearly flow} \times 0.4832 \times PF}{8760} \qquad \text{(EQN 2.1)}$$

When the temperature is above 68°F, this equation applies. Hourly natural gas flow is then (where FC has been normalized by the yearly predicted flow):

$$\text{Hourly Gas Flow} = \text{yearly flow} \times \left[4.849 \times 10^{-4} - 7.0986 \times 10^{-6} T + 1.4614 \times 10^{-6} WS + \frac{0.4832 \times PF}{8760}\right] \qquad \text{(EQN 2.2)}$$

where the temperature is less than or equal to 68°F.

As these equations represent portions of total yearly quantities, these equations apply equally well to bottled (LP) gas which has the same usage characteristics (i.e., its use for cooking, water heating, etc., in addition to space heating).

Table 2.4 Average Hourly Baseline Gas Flows for the LaClede Gas Company (temperature >68°F).

Hour	Composite Average Flow (MSCF)	Proportionality Factor
1	5727	0.84
2	5490	0.80
3	5339	0.78
4	5301	0.77
5	5262	0.77
6	5550	0.81
7	6312	0.92
8	7378	1.08
9	7899	1.15
10	7948	1.16
11	8387	1.22
12	8214	1.20
13	8062	1.18
14	7892	1.15
15	7640	1.11
16	7360	1.07
17	7245	1.06
18	7267	1.06
19	7315	1.07
20	7094	1.04
21	6769	0.99
22	6632	0.97
23	6433	0.94
24 (midnight)	5971	0.87
Average hourly flow	6854	1.00

For other fuels such as fuel oil, coal or coke and wood, the usage characteristics differ in that these fuels are almost totally used for space heating. The demands therefore depends only on temperature and wind speed according to the previously developed equation, without any dependency on a baseline value. Thus:

$T \leq 68°F$

$$\text{Hourly Demand} = \text{yearly total} \times [4.8499 \times 10^{-4} - 7.0986 \quad (\text{EQN 2.3})$$
$$10^{-6}\, T + 1.4614 \times 10^{-6}\, WS]$$

and for $T > 68°F$ the hourly demand is equal to zero.

EVAPORATIVE HYDROCARBON LOSSES

Evaporative losses of hydrocarbons to the atmosphere from dry cleaning plants, surface coating operations and gasoline marketing were considered in this study. Spatial allocation of these emissions were based upon population and commercial land use densities. The temporal allocations were based on the regular 8:00 a.m. to 5:00 p.m. workday or upon the diurnal traffic cycle observed in St. Louis.

Evaporative Hydrocarbon Emissions Estimates

Dry Cleaning Emissions--

The dry cleaning industry uses two basic types of organic solvents in the cleaning of clothes. These are petroleum solvents and chlorinated synthetic solvents (perchloroethylene). Volatile hydrocarbon emissions occur mainly from the hot air tumbler process of drying the solvent soaked garments.

According to the St. Louis County dry cleaning plant survey, 89 percent of dry cleaning establishments use perchloroethylene solvent and 63 percent of all clothes are cleaned with this material. Due to the rising cost of petroleum and increased cost of synthetic solvent (perchloroethylene costs approximately $15/gal.), emission control and recovery equipment has been greatly improved and much more widely used in recent years. Based on the St. Louis County data, 0.53 pounds of hydrocarbons from this type of source are emitted per capita per year. It was assumed that this per capita figure was applicable for the entire AQCR. The emissions occur during normal working hours and are spatially distributed according to the percentage of commercial land use per grid.

A county-by-county breakdown of evaporative hydrocarbon emissions is summarized in Table 3.1.

Thus the yearly county data is allotted to the grid areas by a proportion of commercial land in the grid to the total county value. This is then distributed evenly over the nine hour business day from 8:00 a.m. to 5:00 p.m. in which cleaning is done over the five workdays a week.

Paint Emissions--

Hydrocarbon emissions from the evaporation of solvents from paint have been found to be significant in previous studies.[3] For residential and commercial-institutional area source emissions the type of paints utilized are referred to as "trade-sale" (as distinct from industrial). Trade-sale paints are distributed through retail stores to the general public. The most accurate available statistics for estimating the sales of these paints in AQCR 70 consists of those developed by the National Paint Coating Association (NPCA) in Washington, D.C. These statistics indicate that 21.9 and 10.2 percent of the nationally sold trade-sale paints are sold in the East North Central Region (Ohio, Indiana, Illinois, Michigan, Wisconsin) and the West North Central Region (Minnesota, Iowa, Missouri, Kansas, North Dakota, South Dakota, Nebraska), respectively. The NPCA statistics indicate that in 1973, 424,000,000 gallons of trade-sale paints were sold. Trade-sale paint sales in AQCR 70 were therefore estimated by the following formulas:

$$\text{trade-sale paints sold in Illinois} = \frac{\text{national total} \times 0.219}{\text{pop. of (Ohio + Ind. + Ill. + Mich. + Wisc.)}}$$

$$= 2.32 \text{ gallons per capita}$$

Table 3.1 Hydrocarbon Emissions Inventory for 1973 from Evaporative Sources.

	COUNTY												
	Illinois							Missouri					St. Louis City
	Bond	Clinton	Madison	Monroe	Randolph	St. Clair	Washington		Franklin	Jefferson	St. Charles	St. Louis	
	EMISSIONS (tons/year)												
Gasoline Marketing													
Car Tanks	61	98	807	61	110	733	57		253	365	335	2406	1539
Storage Tanks (100% splash fill)	61	98	807	61	110	733	57		253	365	335	2406	1539
TOTAL GASOLINE MARKETING	122	196	1614	122	220	1466	114		506	730	670	4812	3078
Dry Cleaners													
0.53 lb/capita	3.6	7.8	67	4.8	8.4	76	3.6		16	30	27	250	151
Surface Coating	21	45	390	28	48	441	21		94	177	159	1461	872
TOTAL	147	249	2071	155	276	1983	139		616	937	856	6523	4101

$$\text{trade sale paints sold in Missouri} = \frac{\text{national total} \times 0.102}{\text{pop. of (Minn.+Iowa + Mo.+Ks. + N.D.+S.D. +Neb.)}}$$

$$= 2.70 \text{ gallons per capita}$$

The Technical Director of NPCA, Mr. Ray Conner, estimated that nationally approximately 70 percent of all trade-sale paints were water based.[4] The Boston hydrocarbon study indicated that water based paints contained approximately 3.5 percent by weight volatile hydrocarbons. Mr. Conner estimated that non-water based paints contained approximately 50 percent volatile hydrocarbons. For this study it was therefore assumed that each gallon of trade-sale paint contained approximately 17.5 percent volatile hydrocarbons, by volume or 1.14 pounds of hydrocarbons per gallon of paint. The density of these volatile hydrocarbons was assumed to be 6.5 pounds mass per gallon (the approximate weight of mineral spirits).

Gasoline Marketing Emissions--

Evaporative losses of hydrocarbons in the marketing of gasoline at local service stations occur in two ways--filling losses from underground storage tanks and filling losses and spillage from the filling of automobile tanks.

State totals of gasoline sales were obtained from the Departments of Revenue for the states of Illinois and Missouri. County figures were derived by allocating sales per service station to the number of stations per county as found in the 1972 County Business Patterns.

It was established due to their age that the majority of underground storage tanks are filled by the gravity drop splash fill method with no emission control equipment.[5] These tanks are filled during normal business hours. Emissions estimates based on this produce predictions of

evaporative losses from gasoline marketing approximately 15 percent higher than those derived in the St. Louis County Emissions inventory for gasoline marketing. This agreement is good considering the differences in methodologies.

Spatial Allocations

Emissions from dry cleaning plants and from gasoline marketing operations were apportioned on the basis of the commercial land use within each grid as derived from the EWGCC commercial land use information. The formula utilized was:

$$\text{Grid Annual Dry Cleaning or Gasoline Marketing Emissions} = \frac{\text{area of land in grid under commercial usage (CLUG)}}{\text{total county land area under commercial usage (CLUC)}} \times \text{total county dry cleaning or gasoline marketing emissions}$$

Surface coating emissions from the evaporation of solvents from trade-sale paints were apportioned on the basis of population, as follows:

$$\text{Total Grid Surface Coating Emissions} = \frac{\text{Grid Population (GPOP)}}{\text{County Population (GPOP)}} \times \text{Total County Surface Coating Emissions}$$

Temporal Allocations

The temporal allocations of hydrocarbon emissions are most appropriately based upon the 8:00 a.m. to 5:00 p.m. workday for all emissions except those produced by the filling of automobile gasoline tanks. The hydrocarbon emissions from automobile tank filling account for fifty percent of the gasoline marketing emissions.

The other fifty percent of the gasoline marketing emissions are allocated on the basis of being proportional to the measured diurnal traffic cycle in St. Louis. Figure 3.1 shows this cycle for weekdays, Saturday and Sunday. Table 3.2 shows the weighting factors to be used for this apportionment. In addition to these factors, an allowance for the

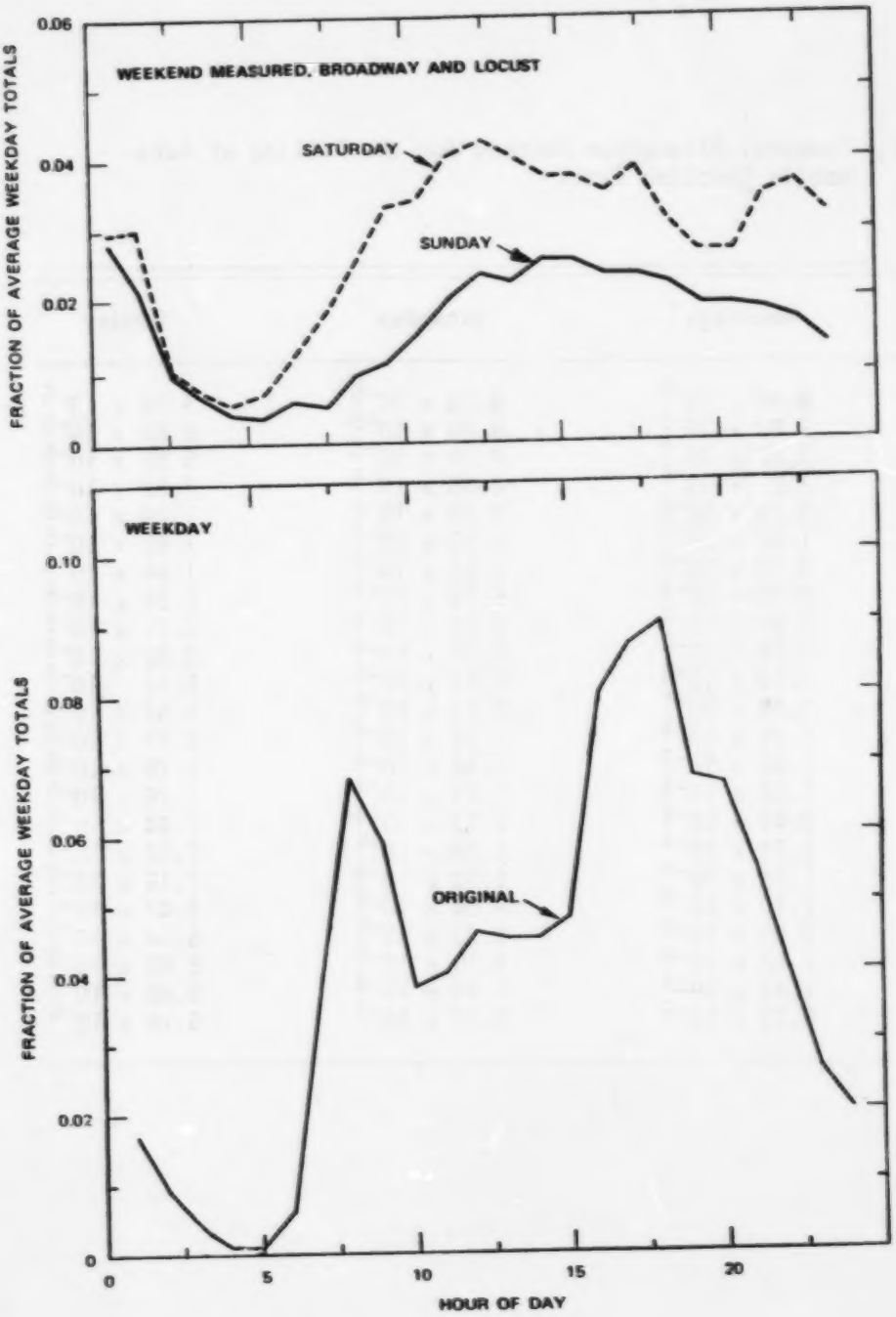

Figure 3.1 DIURNAL EMISSION PATTERNS FOR ST. LOUIS.

Table 3.2 Temporal Allocation Factors for the Filling of Automobile Gasoline Tanks.

Hour	Weekdays	Saturday	Sunday
1	6.45×10^{-5}	9.70×10^{-5}	9.70×10^{-5}
2	5.82×10^{-5}	9.70×10^{-5}	8.09×10^{-5}
3	1.62×10^{-5}	7.12×10^{-5}	5.82×10^{-5}
4	3.23×10^{-6}	2.59×10^{-5}	1.62×10^{-5}
5	3.23×10^{-6}	2.59×10^{-5}	1.29×10^{-5}
6	1.62×10^{-5}	3.23×10^{-5}	1.62×10^{-5}
7	9.70×10^{-5}	4.53×10^{-5}	1.94×10^{-5}
8	2.20×10^{-4}	6.79×10^{-5}	2.59×10^{-5}
9	1.94×10^{-4}	9.70×10^{-5}	3.23×10^{-5}
10	1.29×10^{-4}	1.07×10^{-4}	3.88×10^{-5}
11	1.29×10^{-4}	1.23×10^{-4}	5.18×10^{-5}
12	1.46×10^{-4}	1.29×10^{-4}	6.47×10^{-5}
13	1.46×10^{-4}	1.29×10^{-4}	6.47×10^{-5}
14	1.46×10^{-4}	1.16×10^{-4}	7.76×10^{-5}
15	1.52×10^{-4}	1.13×10^{-4}	7.76×10^{-5}
16	2.43×10^{-4}	1.13×10^{-4}	7.44×10^{-5}
17	2.72×10^{-4}	1.20×10^{-4}	7.12×10^{-5}
18	2.85×10^{-4}	1.10×10^{-4}	7.12×10^{-5}
19	2.10×10^{-4}	9.06×10^{-5}	2.47×10^{-5}
20	2.07×10^{-4}	8.73×10^{-5}	6.14×10^{-5}
21	1.62×10^{-4}	9.70×10^{-5}	5.82×10^{-5}
22	1.23×10^{-4}	1.10×10^{-4}	5.82×10^{-5}
23	9.70×10^{-5}	1.10×10^{-4}	5.18×10^{-5}

variation in seasonal driving habits is necessary. Figure 3.2 shows the monthly gasoline sales for the state of Missouri in 1973 and 1974. Similar data is available for Illinois. As shown, there are marked differences between summer and winter gasoline sales. The monthly sales factor shown in the figure is based upon the average of the 1973 and 1974 values and the relative fraction of sales for a composite average month.

The temporal allocation is then:

(from 8:00 a.m. to 5:00 p.m.) (EQN 3.1)

$$\text{Evaporative HC Emissions} = \frac{1}{2340}^{*} [\text{annual dry cleaning emissions} + \text{annual surface coating emissions} + (0.5 \times \text{annual gasoline marketing emissions} \times \text{monthly sales factor})] + (\text{automobile allocation factor} \times 0.5 \times \text{annual gasoline marketing emissions} \times \text{monthly sales factor})$$

(from 5:00 p.m. to 8:00 a.m.) (EQN 3.2)

$$\text{Evaporative HC Emissions} = \text{automobile allocation factor} \times 0.5 \text{ annual gasoline marketing emissions} \times \text{monthly sales factor}$$

* This number is based on a workday from 8:00 a.m. to 5:00 p.m., five days a week and 52 weeks per year.

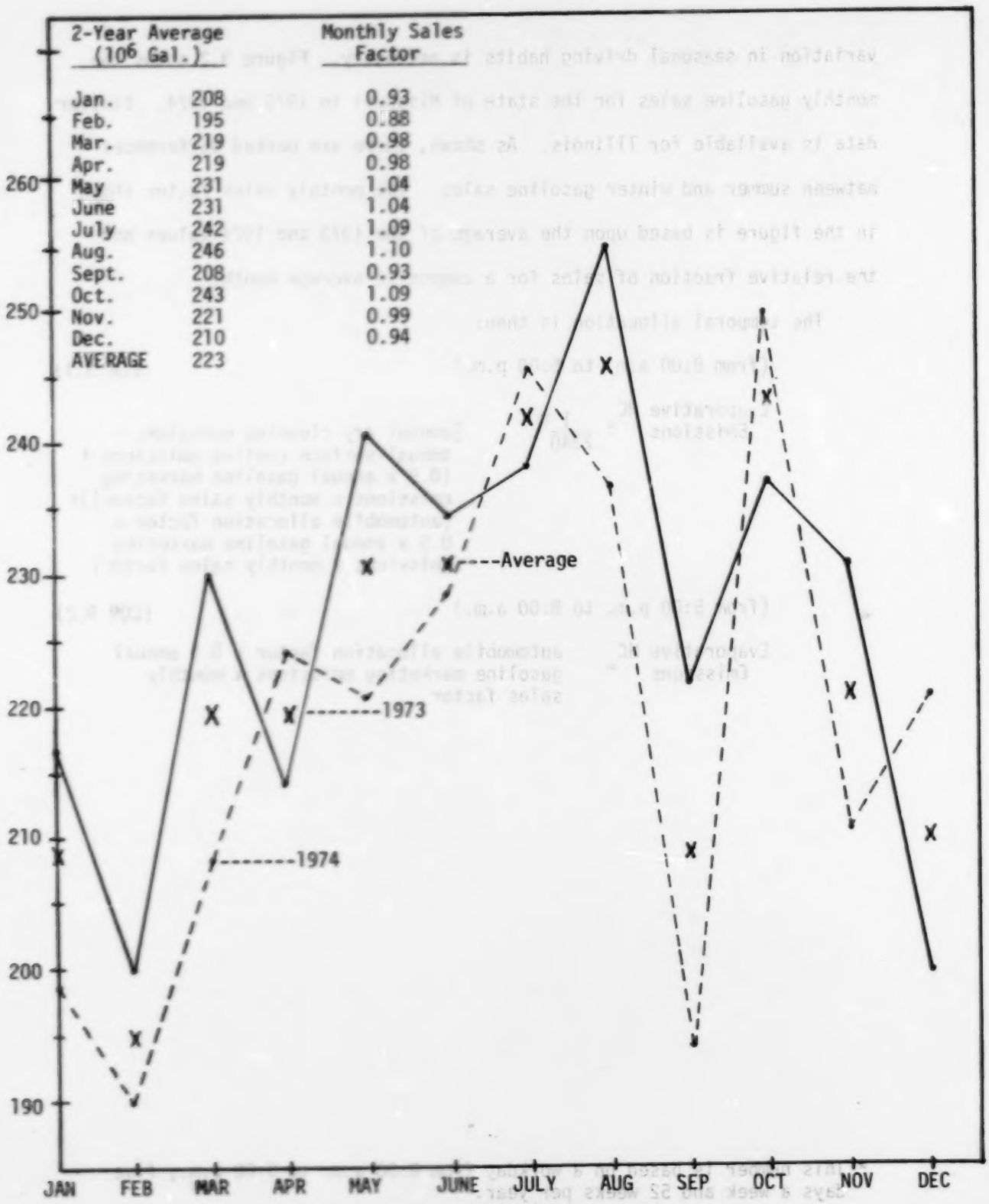

Figure 3.2 State of Missouri Gasoline Sales.

SOLID WASTE DISPOSAL

Emissions from solid waste disposal through open burning and incineration were considered in this study. Conversations with the St. Louis County Air Pollution Control Board[6] and with the Missouri Air Conservation Commission[7] indicated that open burning was banned from the populous areas of AQCR 70. It is allowed by law only where no public or commercial refuse collection service is available and in places where population density is less than 100 dwelling units or less per square mile. The emissions from open burning are considered insignificant in this study.

Information sources on solid waste incineration included a nationwide study and the emission inventory prepared by St. Louis County. The latter source of information appeared to be the most reliable as it included actual emissions data other than nationwide statistics. This study indicated that residential incineration was negligible. According to the Pollution Control Regulations for the St. Louis Metropolitan Area, only multiple chamber incinerators may be used and must not exceed 0.3 grains of particulate per dry standard cubic foot of exhaust gas. Since the emission standards are stringent and the cost of multiple chambered units high, residential incineration emissions were considered insignificant in this study. The only significant source of incineration pertinent to this study was the commercial-institutional area source category.

Treating the St. Louis County figures as being representative of the entire AQCR, Table 4.1 summarizes the emissions estimates from solid waste disposal by county.

The spatial and temporal allocation procedures are similar to those for emissions from the dry cleaning process; that is, in proportion to the commercial-institutional land use in each grid square, and an 8:00 a.m. to 5:00 p.m. workday.

Table 4.1 Solid Waste Commercial-Institutional Incineration Emissions (tons/year) in AQCR 70 for 1973.

County	Part.	SO_x	NO_x	HC	CO
Missouri					
Franklin	3.21	0.38	0.58	2.57	5.13
Jefferson	6.05	0.73	1.09	4.84	9.67
St. Charles	5.47	0.66	0.98	4.37	8.75
St. Louis	50.00	6.00	9.00	40.00	80.00
St. Louis City	29.86	3.58	5.38	23.89	47.78
Illinois					
Bond	0.74	0.09	0.13	0.59	1.18
Clinton	1.52	0.18	0.27	1.22	2.44
Madison	13.30	1.60	2.40	10.68	21.37
Monroe	0.95	0.11	0.17	0.76	1.51
Randolph	1.63	0.20	0.29	1.30	2.61
St. Clair	15.09	1.81	2.72	12.07	24.14
Washington	0.74	0.09	0.13	0.59	1.18

STRUCTURAL FIRES

Data was not available for wildfires and forest fires. The available data on structural fires is such that a high degree of reliability cannot be placed on the emissions estimates. The available data included: 1) the number of fires and dollar damage on a monthly basis for Illinois,[8] 2) statewide statistics on the total number of fires (10,000) doing $45,500,000 worth of damage in 1974;[9] and 3) nationwide statistics indicating that 40 percent of the typical structure is consumed in a fire and that the average structure contains approximately 17 tons of combustible material.[10]

For Missouri the statewide figures were disaggregated to the county level on the basis of population. Using the emission factors in AP-42 for open burning of municipal solid waste, the emission estimates were derived. These values are summarized in Table 5.1

The spatial apportionment is most appropriately conducted on the basis of the number of housing units per tract:

$$\text{Grid Emissions} = \frac{\text{no. of housing units in grid}}{\text{no. of housing units in county}} \times \text{County Emissions}$$

The temporal distribution of these fires is random. The apportionment figures can be utilized on an annual basis as a reasonable approximation. However, for the purpose of the calibration of dispersion models, the only appropriate approach is for the modeler to be aware of whether or not a structural fire has occurred that may affect short-term model results. The fire can be treated as a ground level point source. An estimate of emissions can be included in the grid area based upon 40 percent of the 17 tons of combustible material being consumed in a four hour period using the emission factors for incinerator without controls from AP-42.

Table 5.1 Estimated Annual 1973 Emissions (tons/year) from Structural Fires in AQCR 70.

County	Part.	SO_x	CO	HC	NO_x
Illinois					
Bond	0.7	<0.1	3.8	1.3	0.3
Clinton	2.1	0.1	11.0	3.9	0.8
Madison	49.7	3.1	264.2	93.2	18.7
Monroe	2.2	0.1	11.6	4.1	0.8
Randolph	3.8	0.2	19.9	7.0	1.4
St. Clair	56.2	3.5	298.5	105.4	21.1
Washington	1.1	0.1	6.1	2.1	0.4
Missouri					
Franklin	7.0	0.4	37.3	13.2	2.6
Jefferson	13.2	0.8	70.2	24.8	5.0
St. Charles	12.0	0.8	63.6	22.4	4.5
St. Louis	109.3	6.8	580.9	205.0	41.0
St. Louis City	65.3	4.1	347.1	122.5	24.5

SUMMARY

General

The Regional Air Pollution Study has unique requirements of its component emission inventories. Generally it requires degrees of spatial and temporal resolution that have not been previously achieved. This document brings together data on fuel usage, land use, sales of gasoline and paints, the use of dry cleaning fluids, solid waste disposal and uncontrolled fires for the St. Louis region and develops methodologies for estimating the pollutant emissions from stationary residential and commercial-institutional area sources on an hour-by-hour basis for components of a spatial grid system developed for RAPS.

The methodologies presented in this document are a series of sub-elements integrated into a single system for deriving the required emission data. This system seeks to provide the best emission estimates possible from the available data. In order to provide the RAPS with as much flexibility as possible to meet the multiple and varied demands upon it, the inventory is presented as direct statements of weight of pollutant emitted by this class of source as a function of location for every hour.

Specific Results

Space Heating - The emissions from space heating were based upon the emission factors utilized by the National Emissions Data System and from AP-42 for each fuel. The distribution within the RAPS grid system was determined by allocating total county fuel use for residential, and, in a separate calculation, commercial-institutional fuel usage to each grid area in proportion to the number of units using that fuel in the grid area. The temporal fuel use variation and variation with meteorological

parameters was established by statistically analyzing the detailed data available on gas use. This analysis identified a base component of usage which is largely independent of meteorological influence and has a distinct relationship with the time of day. The remaining component was shown to be strongly affected by the ambient temperature and wind velocity.

Evaporative Emissions

The major components of residential and commercial-institutional area sources of evaporated hydrocarbons were identified as surface coating (primarily painting), gasoline handling, and dry cleaning. Characteristic emissions on a per capita basis were established and the emissions determined for each grid area by allocating the total projected county emissions in proportion to commercial land use in the grid area for gasoline handling and dry cleaning, and in proportion to population for surface coating.

Structural Fires and Solid Waste Disposal

Emissions from structural fires were difficult to quantify; however, average data was used and total estimated county emissions were allocated to grid areas based on the number of homes in the grid. However, it was realized that significant structural fires would be best handled as a point source.

Emissions from the disposal of solid wastes is largely restricted to commercial-institutional enterprises and large incinerators because of the restrictive air pollution regulations. Thus the NEDS county emissions were allocated to grid areas in proportion to the commercial-institutional land use in the grids.

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10. Derived from data provided by the National Fire Protection Association of Boston, Massachusetts.

APPENDIX A

Description of the Annual Emission Inventory Calculation

Emissions from residential space heating were determined by allocating total county residential fuel usage to each grid base on the number of homes in the grid using a given fuel type:

$$SHR_{i,j,k} = \frac{NHGFU_{i,j}}{NHC_{i,j}} \times TCFUR_{i,j} \times EF_{j,k}$$

Equations and Input Parameters

Where: $SHR_{i,j,k}$ = residential space heating emissions of pollutant k from fuel type j in grid number i

$NHGFU_{i,j}$ = number of homes in grid i using fuel type j

$NHC_{j,f}$ = number of homes using fuel type j in the county f in which grid is located

$TCFUR_{j,f}$ = total residential usage of fuel type j in the county f in which grid is located

$EF_{j,k}$ = emission factor (AP-42) for fuel type j and pollutant k.

Emissions from commercial fuel usage was determined by allocating total commercial fuel usage in a given county to each grid based on commercial land use within a grid and the ratio of the number of homes using a given fuel type in a grid to the total number of homes within that grid.

$$COM_{i,j,k} = \frac{CLUG_i}{CLUC_f} \times \frac{NHGFU_{i,j}}{HG_i} \times TCFUC_{i,j} \times EF_{j,k} \times \frac{NHC_{j,f}}{NHCT_f}$$

Where: $COM_{i,j,k}$ = emissions from commercial fuel usage of pollutant k from fuel type j in grid number i

$CLUG_i$ = commercial land use (km^2) in grid i

$CLUC_f$ = commercial land use (km^2) in the county in which grid is located

NHG_i = total number of homes in grid i

$TCFUC_{j,f}$ = total commerical usage of fuel type j in the county

$NCH_{j,f}$ = is defined above

$NHCT_f$ = total number of homes in county f

Evaporative hydrocarbon emissions for the three processes indicated below were determined for each grid by allocating total county emissions from the three processes on the basis shown.

Process	Allocation Basis
1) Surface Coating	Grid Population
2) Gasoline Handling	Commercial Land Use
3) Dry Cleaning	Commercial Land Use

$$GHCE_{i,1} = CHCE_{1,f} \times \frac{GPOP_i}{CPOP_f}$$

$$GHCE_{i,2} = CHCE_{2,f} \times \frac{CLUG_i}{CLUC_f}$$

$$GHCE_{i,3} = CHCE_{3,f} \times \frac{CLUG_i}{CLUC_f}$$

Where: $GHCE_{i,j}$ = evaporative hydrocarbon emissions in grid i from process j

$CHCE_{j,f}$ = total county f emissions from process j

$GPOP_i$ = population of grid i

$CPOP_f$ = population of county in which grid is located

Emissions from structural fires were determined by allocating total county emissions to each grid based on the number of homes in the grid.

$$EMSF_{i,k} = ESFC_{k,f} \times \frac{NHG_i}{NHCT_f}$$

Where: $EMSF_{i,k}$ = emissions from structural fires of pollutant k in grid i

$ESFC_{k,f}$ = total county emissions from structural fires of pollutant k from county in which grid is located

$NHCT_f$ = total number of homes in county

Emissions from the disposal of solid wastes was determined by allocating total county emissions to each grid based on commercial land use within that grid.

$$ESW_{i,k} = ESWC_{k,f} \times \frac{CLUG_i}{CLUCf}$$

Where: $ESW_{i,k}$ = emissions from solid waste disposal of pollutant k in grid i

$ESWC_{k,f}$ = total county emissions from solid waste disposal of pollutant k for county in which grid is located.

APPENDIX B

Sample Calculation

I. EMISSION FACTORS

Fuel Type	Pollutant				
	Part	SO_2	CO	HC	NO_x
Bituminous Coal (tons/ton)					
Domestic	0.0100	0.00475	0.0450	0.0100	0.0015
Commercial	0.0140	0.00475	0.0036	0.0010	0.0046
Residual Oil (tons/10^3 gal)					
Commercial	0.0115	0.1590	0.0020	0.0015	0.0300
Distillate Oil (tons/10^3 gal)					
Domestic	0.0050	0.0144	0.0025	0.0015	0.0060
Commercial	0.0075	0.0144	0.0020	0.0015	0.0300
Natural Gas (tons/10^6cu. ft.)					
Domestic	0.0050	0.0003	0.0100	0.0040	0.0400
Commercial	0.0050	0.0003	0.0100	0.0040	0.0600
Bottled (LP) Gas (tons/10^3gal)					
Domestic	0.00095	7.2×10^{-6}	0.0010	0.0004	0.0400

II. COUNTY AND GRID ANNUAL DATA

A. Attributes of County No. 2:*

Population		CPOP	568100
Commercial Land Use		CLUC	11.965 km^2
Number of Homes Using Fuel Type	1 Oil	NHC	16949
	2 NG		186093
	3 LPG		2523
	4 Coal		3375
Total Residential Usage of Fuel Type (Table 2.1) (TCFUR)	1		13560
	2		26400
	3		16619
	4		18560
Total Commercial Usage of Fuel Type (Table 2.1) (TCFUC)	1 Dist-35,000 Residents		0
	2		11100
	3		0
	4		112000
Total Evaporative Hydrocarbon Emissions (Table 3.1) (CHCE)	1		872
	2		3078
	3		151
Total County Emissions from Structural Fires Pollutant (Table 5.1) (ESFC)	1 Part		65 Tons
	2 SO_2		4
	3 CO^2		347
	4 HC		123
	5 NO_x		25
Total County Emissions from Solid Waste Disposal Pollutant (Table 4.1) (ESWC)	1		30 Tons
	2		4
	3		48
	4		24
	5		5
Total Number of Occupied Homes in the County (NHCT)	= 215479		

*All units are standard NEDS units (emissions as tons/year, fuel oil as 10^3 gal/year, natural gas as 10^6 cu ft/year, LPG as 10^3 gal/year, and coal as tons/year.

B. Attributes for Grid No. 895, located in the City of St. Louis which is treated as County No. 2:

Population		GPOP	5096
Area			1.0 km^2
Commercial Land Use		CLUG	0.15 km^2
Number of Homes		NHG	1547
Homes Using Fuel Type	1	NHGFU	139
	2		1302
	3		26
	4		41

III. GRID EMISSION CALCULATIONS FOR POLLUTANT NO. 4 (HYDROCARBONS)

A. Residential Fuel Consumption

1. Fuel Type 1, Fuel Oil

$$\frac{NHGFU(1)}{NHC(1)} \times TCFUR(1) \times EF = \frac{139}{16949} \times 13560(10^3 gal) \times$$

$$0.0015(tons/10^3 gal) = 0.1668 \text{ (tons/year)}$$

2. Fuel Type 2, Natural Gas

$$\frac{NHGFU(2)}{NHC(1)} \times TCFUR(2) \times EF = \frac{1302}{186093} \times 26{,}400(10^6 cu.ft.) \times$$

$$.0004 (tons/10^6 cu.ft.) = 0.7388 \text{ (tons/year)}$$

3. All other Fuel Types similar

B. Commercial and Institutional Fuel Usage

1. Fuel Type 1, Fuel Oil

a. Distillate Oil

$$\frac{CLUG}{CLUC} \times \frac{NHGFU(1)}{NHG} \times \frac{NHCT}{NHC(1)} \times EF \times CFT(dist.) =$$

$$\frac{0.15}{11.965} \times \frac{139}{1547} \times \frac{215479}{16949} \times 0.0015 \left(\frac{tons}{10^3 gal}\right) \times$$

$$35000(10^3 gal) = 0.7518 \text{ (tons/year)}$$

b. Residual Oil

$$\frac{CLUG}{CLUC} \times EF \times TCFUC \text{ (res.)} = \frac{0.15}{11.965} \times .0015 (tons/10^3 gal) \times$$

$$0(10^3 gal) = 0.0 \text{ (tons/year)}$$

c. Total Commercial Fuel Oil HC Emissions

Results of "a" + "b" = 0.7518 x 0.0 = 0.7518 (tons/year)

2. Fuel Type 2, Natural Gas

$$\frac{CLUG}{CLUC} \times \frac{NHGFU(2)}{NHG} \times \frac{NHCT}{NHC(2)} \times EF \times TCFUC(2) =$$

$$\frac{0.15}{11.965} \times \frac{1302}{1547} \times \frac{215479}{186093} \times .004(\text{tons}/10^6\text{cu.ft.}) \times$$

$$11100\ (10^6\text{cu.ft.}) = 0.5424(\text{tons/year})$$

3. All other Fuel Types similar to 1a and 2 above.

C. Emissions from Structural Fires

$$ESFC(4) \times \frac{NHG}{NHCT} = 123(\text{tons}) \times \frac{1547}{215479} =$$

$$0.8831(\text{tons/year})$$

D. Emissions from Solid Waste Disposal

$$ESWC(4) \times \frac{CLUG}{CLUC} = 24(\text{tons}) \frac{0.15}{11.965} = 0.3009(\text{tons/year})$$

E. Evaporative Hydrocarbons

1. Surface Coating

$$CHCE(1) \times \frac{GPOP}{CPOP} = 872(\text{tons}) \times \frac{5096}{568100} = 7.822(\text{tons/year})$$

2. Gasoline Handling

$$CHCE(2) \times \frac{CLUG}{CLUC} = 3078(\text{tons}) \times \frac{0.15}{11.965} = 38.5875(\text{tons/year})$$

3. Dry Cleaning

$$CHCE(3) \times \frac{CLUG}{CLUC} = 151(\text{tons}) \times \frac{0.15}{11.965} = 1.8930(\text{tons/year})$$

IV. GRID HOURLY EMISSIONS FOR HC

A. Hourly Characterization

1. Time: 8:00 a.m. = 9:00 a.m.
2. Wind Speed: 15 mph
3. Temperature: 40°F
4. Day: Tuesday
5. Month: February

B. Fuel Oil

[Residential + Commercial & Institutional Fuel Oil Yearly Emissions] x [$4.8499 \times 10^{-4} - 7.0986 \times 10^{-6}T + 1.4614 \times 10^{-6}WS$] = [Results III A.1 plus III B.1] x Eqn =

[0.1668 + 0.7518] (tons/year) x [$4.8499 \times 10^{-4} - 7.0986 \times 10^{-6} \times (40) + 1.4614 \times 10^{-6}(15)$]$(\frac{year}{hour})$ = $(0.9186) \times (7.9086 \times 10^{-4})$ =

7.2648×10^{-4} tons/hour

C. Natural Gas

[Residential + Commercial & Institutional Natural Gas Yearly Emissions] x $4.8499 \times 10^{-4} - 7.0986 \times 10^{-6}T + 1.4614 \times 10^{-6}WS +$

$\frac{0.4832}{8760} \times PF$] = [Results III A.2 and III B.2] x [Eqn with PF from Table 2.4] = [0.7388 + 0.5424] $(\frac{tons}{year})$ x [$4.8499 \times 10^{-4} -$

$7.0986 \times 10^{-6} \times (40) + 1.4614 \times 10^{-6} \times (15) + \frac{0.4832 \times 1.15}{8760}$]

$(\frac{years}{hours})$ = $(1.2812) \times (8.5429 \times 10^{-4})$ $(\frac{tons}{hour})$ = 1.0945×10^{-3} tons/hour

D. Other Fuels

1. LP Gas - same as C above
2. Coal - same as B above

E. Structural Fires

Hourly emissions based on a random distribution may be used. However, for use in dispersion models these values would be meaningless. For this source, the modeller must investigate the nature of any fires. The random distribution is obtained by dividing the yearly figure by 8760.

F. Solid Waste

[Results from III D] x $4.27 \times 10^{-4} = 1.28 \times 10^{-4} \frac{\text{tons}}{\text{hour}}$

G. Evaporative Hydrocarbons

4.27×10^{-4} x [annual dry cleaning emissions + surface coating emissions + (0.5 x gasoline marketing emissions x monthly sales factor*)] + (automobile allocation factor** x 0.5 x gasoline marketing emissions x monthly sales factor) = 4.27×10^{-4} x [1.8930 + 7.822 + (0.5 x 38.5875 x 0.88)] + (1.94×10^{-4} x 0.5 x 38.5875 x 0.88) = $1.14 \times 10^{-2} + 0.33 \times 10^{-2} = 1.47 \times 10^{-2}$ tons/hour